Middle

LA4: Standard Deviation

Purpose

To introduce middle students to using standard deviation for analysis

Student Outcomes

Students will be able to use standard deviation to analyze a data set.

Overview

Students will organize and analyze GLOBE data using simple statistics, including standard deviation, to answer their research questions and to accept or refute their hypotheses.

Time

Task 1: 90 minutes

Task 2: 45 minutes

Level

Middle: Grades 5 and up

Key Concepts

Results of similar investigations vary.
Careful work and records help determine reasons for varying results.
Explanations involve observations.
Evidence and logic are used to back claims.
Similar steps are used to conduct investigations.
Expectations can affect outcomes.
Unexpected findings lead to new investigations.
Varying results may be trivial or significant.
Communication is important in science.

Skills

Measuring, collecting and *organizing* data
Recognizing and *describing* patterns
Estimating
Interpreting graphs
Interpreting tables
Calculating central tendency
Calculating and *interpreting* standard deviation
Creating and *interpreting* histograms
Using statistical methods to describe, analyze, and draw conclusions

Processes

Scientific method
Student inquiry

Materials and Tools

GLOBE Science Log
GLOBE Source Book
Pencils
World atlas (recommended)

Task 1

How High Does Our Step Stool Need to Be? Work Sheet 1
How High Does Our Step Stool Need to Be? Work Sheet 2

Preparation

Students should have mastered the skills required in the preceding *Inquiry Learning Activities*

Prerequisites

Basic arithmetic: adding, subtracting, multiplying, dividing

Calculating mean

Task 1 – Reading the Rain Gauge
Determine how high your step stool needs to be to see the rain gauge at eye level.

What To Do and How To Do It

Problem:
Your rain gauge is mounted with your atmosphere shelter so that the top of the inner tube inside the rain gauge is two meters above the ground. It is too tall for the students to be able to read the rainfall amount at eye level, so they need to buy a step stool. How can you determine the best height for the step stool?

Use *Calculating Standard Deviation Work Sheet 1.*

1. Find the height of each member of the class.
2. Calculate the mean height of the class.
3. Fill in the Student Name (or number) and Height.
4. For each student, find and record the difference between the mean and the student height.
5. Square the difference (to get rid of negative numbers)
6. Record the sum of the differences squared.
7. Record the number of students in the class.
8. Calculate the average of the differences squared.
9. Find the square root of the average of the differences squared. This is the *standard deviation** (SD). 1 SD is defined as the mean of the data set + or – the standard deviation. If your class has a *normal distribution** 68% of the students in the class are within $\pm$ 1 standard deviation, 96% of the students are within $\pm$ 2 SD of the mean class height, and 99% of the students are within 3 SD of the mean class height.

Use *Using Standard Deviation Work Sheet 2.*

1. How high would the stool need to be so that 68% of the students could read the rain gauge at eye level no matter how much rain was in it?
2. How high would the stool need to be so that 96% of the students could read it?

Example:
The mean height of the class is 1.2 m (120 cm). One standard deviation is 0.2 m (20 cm). Therefore, students between 1.0 m (100 cm) and 1.4 m (140 cm) will be within 1 SD of the mean. In the 68th percentile, for the shortest student, at 1.0 m, to be able to read the rain gauge, at 2.0 m, the stool needs to be 1.0 meter tall.

Standard Deviation:
Definition: The standard deviation of a collection of numbers is the square root of (the difference between the mean of the squares of the numbers and the square of the mean of the numbers).

Normal Distribution:
Definition: A frequency distribution represented by a bell-shaped curve representing the distribution of a series of values of a variable.

How High Does Our Step Stool Need to Be?

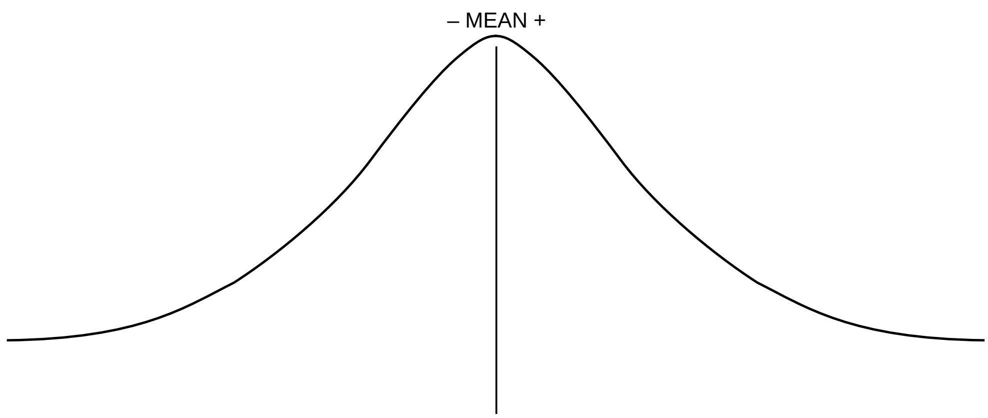
Work Sheet 1 – Calculating the Standard Deviation

Mean height of students in class = _____________ cm

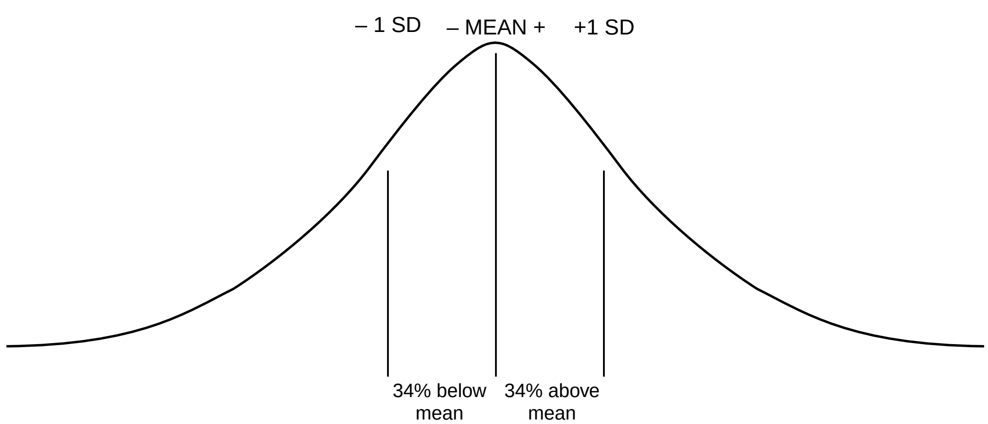
Student Name	Height (cm)	Difference (cm) between class mean and height	Difference Squared
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			
16.			
17.			
18.			
19.			
20.			
21.			
22.			
23.			
24.			
25.			
26.			
27.			
28.			
29.			
30.			
Total of the Differences Squared (T)			
Number of Students (S)			
Average of the Differences Squared (T/S)			
Square Root of the Average = Standard Deviation ($\sqrt{T/S}$)			

How High Does Our Step Stool Need to Be?

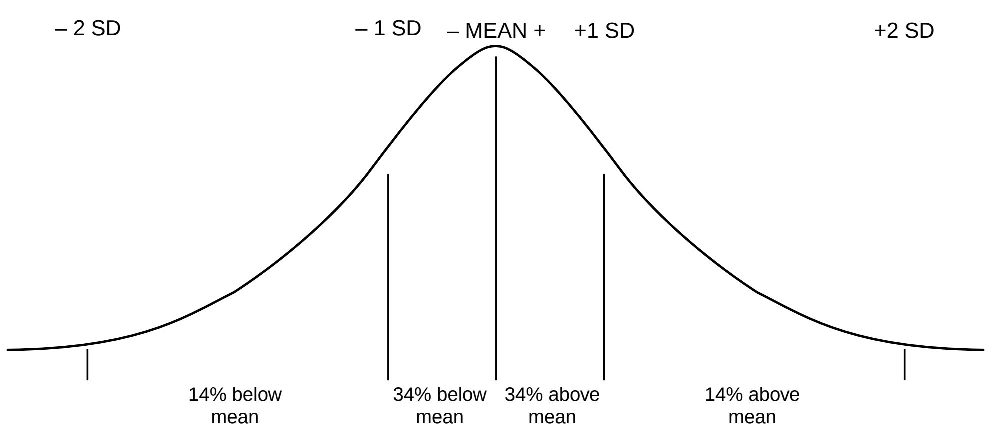
Work Sheet 2 – Using the Standard Deviation



1. How high does the stool need to be so 68% of the students can read it? ____________



2. How high should the stool be so 96% of students can read it? (mean – 2 SD =_______cm)



Task 2 – Classifying pH Data
Determine how to classify the pH data

What to Do and How to Do It

Students at a school in the Northeast USA found that their average surface water pH for 2000 was 6.8. They wondered if their school had pH values that were low or high for their region, so they compared the surface water pH at their school with that of other schools in their region. They created a map and table of data for the area. See map/table of *Northeast USA Average pH 2000 below* or in Source Book.

Values for Northeast USA - Average Water pH 2000			
8.3	7.1	6.2	5.2
7.7	6.9	6.2	5.1
7.5	6.5	5.9	

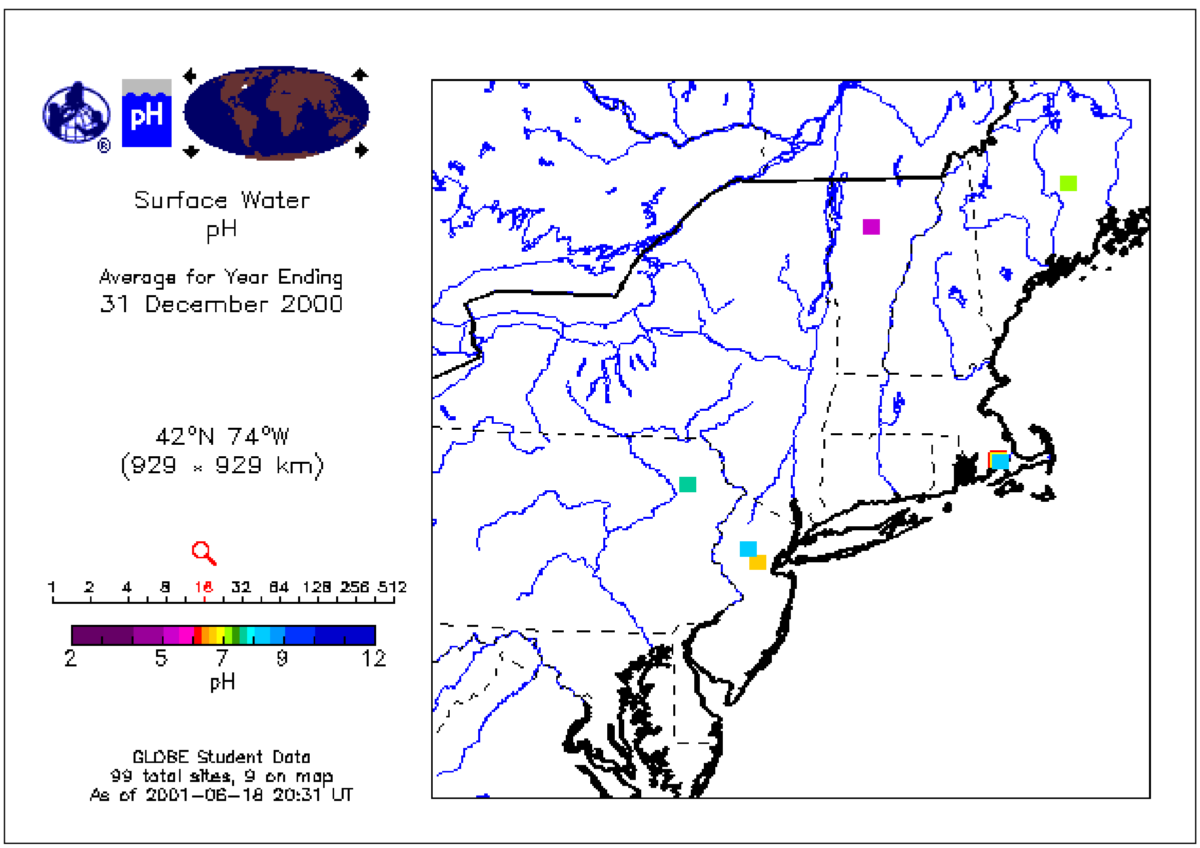
Within your group, look at the pH data and determine the values that would be considered 'high', 'medium' and 'low'.

1. Share the results with other groups in the class. How were the determinations made? Were they consistent? What methods worked for determining the classes of data?
2. Calculate the mean and SD for this data set. Using one SD as the medium range, how do your classes compare? What are the advantages/disadvantages of using SD?
3. Did the students have *average* pH for their region?

Further Investigations

Students were interested in examining the pattern of surface water pH in Europe. They wanted to know where areas of low, medium, and high pH existed. How could they determine values for 'low', 'medium', and 'high'? See map/table of *Europe Average Surface Water pH 2000* in the GLOBE Source Book.

When they mapped pH values in Europe for 2000 they noticed only one school, Staatliche Realschule Burglengenfeld in Germany, showed up bright red on the map. Does this school have pH values outside 'normal' range for the area? See zoom of map of *Europe Average Surface Water pH*.



Middle

LA5: Analysis with Isopleth Maps

Purpose

To introduce students to making and using isopleth maps for analysis

Student Outcomes

Students will be able to create a simple isopleth map and use isopleth maps to interpret spatial variation in data.

Overview

Students will first learn to make a simple isopleth map. They will then use GLOBE data to create isopleth maps and use the maps created on the GLOBE visualization pages to explore regional climatic variations.

Time

40-50 minutes per task or map

Level

Middle; Grades 4 and up

Key Concepts

Isopleth maps are models of reality.
Results of similar investigations vary.
Variations in topography affect regional climate patterns.

Skills

Recognizing and *describing* patterns
Organizing data
Grouping
Estimating
Creating an isopleth map
Interpreting an isopleth map
Drawing conclusions

Processes

Student inquiry
Scientific method
Energy cycle

Materials and Tools

GLOBE Science Log
GLOBE Source Book
Pencil/eraser
Colored pencils
Task 1
Drawing an Isopleth MapWork Sheet
Task 2
Regional data map student templates
Atlas

Preparation

Have students examine some of the maps on the GLOBE visualization Web pages or in the GLOBE Source Book.

Prerequisites

None

Preparation

We can never gather data from every point on a map. An isopleth map is used to show patterns of data on a map or to fill in missing data. An isopleth map is a map with lines connecting points of equal value. These lines are called isolines. One common use of isopleth maps are weather maps that predict temperatures. The temperature ranges are illustrated with colors. An area with the same color shows a range of temperatures between two isolines. Another common type of isopleth map is a contour map, a map with lines connecting points of equal elevation.

Thus, an isopleth map is a hypothesis or model of what the map would look like if data were available.

Drawing your own isopleth maps is an excellent way to understand how some of these models are created and how to interpret them. For more information on how the GLOBE visualizations are created you can go to the Visualization Help Page.

Task 1
Draw a simple isopleth map.

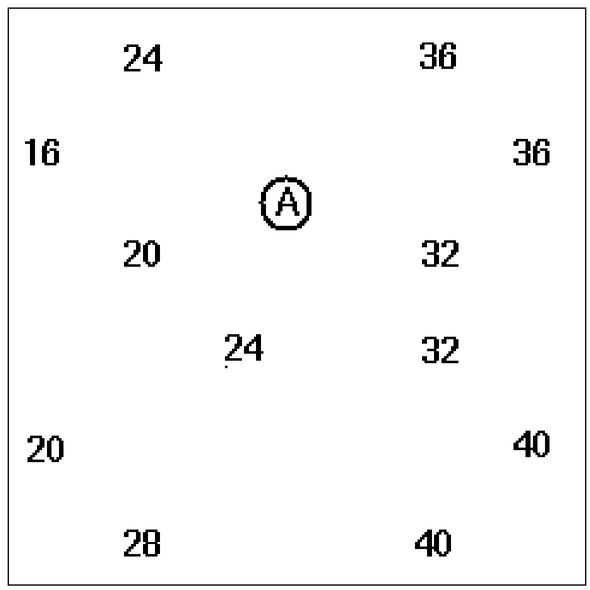
What To Do and How To Do It

Follow the instructions adapted from the GLOBE visualization pages to learn to create your own isopleth maps.

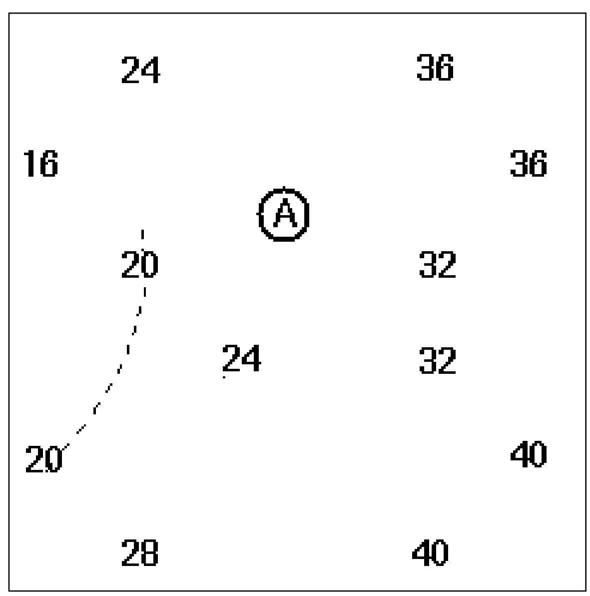
Drawing an Isopleth Map

We have plotted some temperature data points. It would be difficult to determine the value at point A (what do you think it is?) without drawing some *isolines* first. An isoline is a line connecting points having the same data value. An isoline connecting points of equal temperature is called an *isotherm*.

Since we have 2 data points that are 20, we can draw a line connecting them.

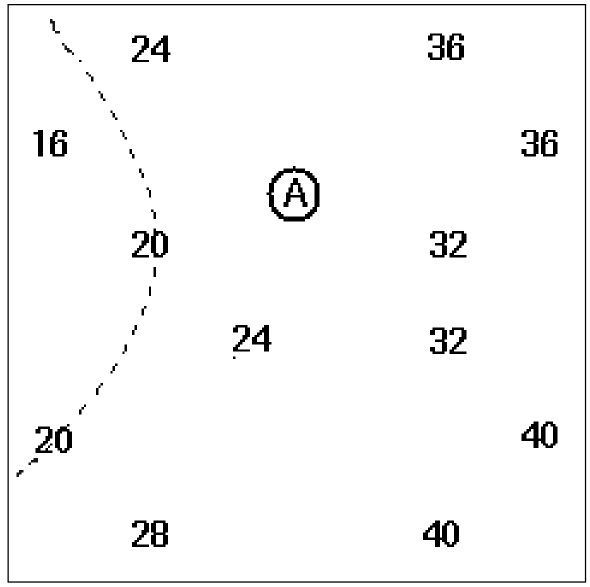


This is how the plot should look. What do we do now? There are no other 20 degree data points, but we do have two points in the upper left corner that are 16 and 24 degrees. We assume a line of *gradation* between the points. This is like a number line between the points. We assume the temperature between 16 and 24 uniformly rises. Since 20 is halfway between 16 and 24, we *interpolate*, or hypothesize, there is a 20 degree temperature point right in the middle between 16 and 24. Now we can extend our line between these two points.



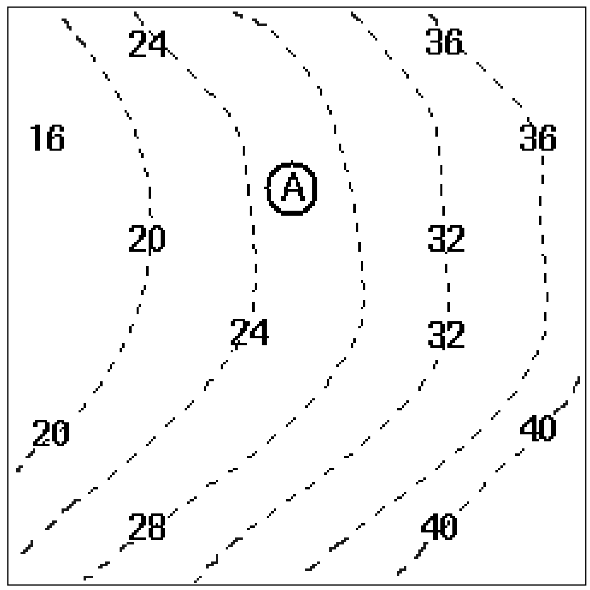
We have now completed the isotherm for 20 degrees. Any point to the *left* of the dashed line is colder than 20 degrees, and any point to the *right* of the line is warmer than 20 degrees. Any point on the line is assumed to be 20 degrees.

This procedure is followed until you have drawn a line for each value you want. Usually, isolines are drawn at a fixed range of values, called the *interval.* Here, we will draw lines every 4 degrees. Thus, there will be isotherms for 20, 24, 28, 32, 36 and 40 degrees.

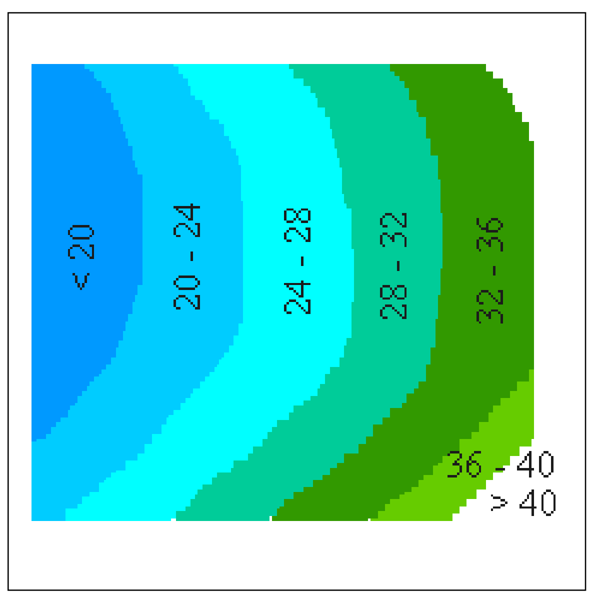


This is the final isotherm map. Since point A lies between the lines representing 24 and 28 degrees, the temperature at point A is between 24 and 28 degrees—or about 26.

Notice that this map looks different from the ones made from your GLOBE student data. Instead of using colors to show the temperatures, we have used labeled lines.

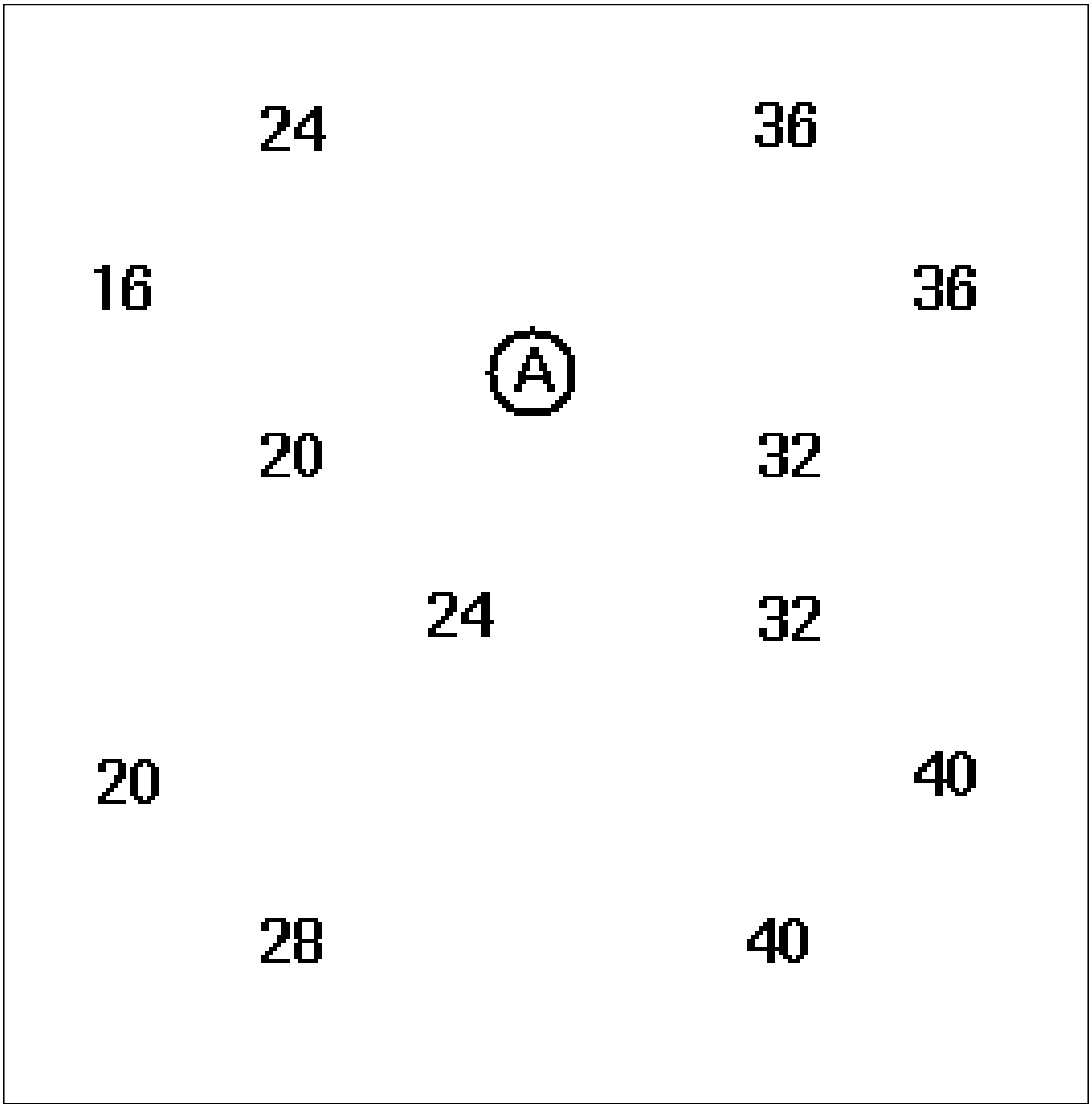


We can make a color isotherm map from this simply by filling in the area between each line with a distinct color, as shown.



Drawing an Isopleth Map

Work Sheet



Title: ______________________________

Interval: ______________________________

A few rules to remember as you create isopleth maps:

1. Isolines never cross each other. Since each line represents a unique value, a point where two lines crossed would have two values. This is not possible! It cannot be both 24 and 28 degrees at the same time.
2. Isolines never end on the map. They either go to the edge of the map or make a circle within the map.
3. Isolines should always be labeled and the interval should be stated on the map.

Note: Isolines can be drawn to connect any type of data displayed on a map. Different types of data are given special names. You have already learned *isotherm*, lines connecting points of equal temperature. Other common terms are:

Isohyets – lines of equal rainfall

Isobars – lines of equal barometric pressure

Contours – lines of equal elevation

Task 2
Create isotherm maps to compare regional variations in temperature to global patterns.

What To Do and How To Do It

1. Examine the global yearly average maximum temperature map. Describe the general pattern of temperature on the map in your Science Log
2. Create an isopleth map from the data map provided for the northeastern USA. Begin at 20 degrees and use an interval of 3 degrees. Does this map seem to follow what you would expect to find on a global scale?
3. Create an isopleth map from the data map provided for Benin. Begin at 32 degrees and use an interval of 2 degrees. Note that isolated values (such as might be found on a mountain top) may have to have there own isoline drawn as a small circle. Does the temperature gradually increase or decrease as you move northward in Benin? What variables might be explored to explain the regional pattern of temperature?
4. Create an isopleth map from the data map provided for Japan and South Korea. Begin at 20 degrees and use an interval of 2 degrees. Note that isolines may increase then decrease on a map, such as when you are going over a mountain. What is the general pattern on this map? What factors might explain differences in the pattern between the global map and your regional map?
5. Create an isopleth map from the data map of Germany and Czech Republic. What type of pattern do you identify? How can you explain this pattern. Hint: compare your map to a contour map.
6. Compare your isopleth maps to the GLOBE visualization maps in the Source Book. Remember that isopleth mapping is based on assumptions of data lines. Examine how your estimations differ from that of the computer generated map.
7. How might more data points change the isopleth lines on your maps?

Middle

LA6: Planning an Investigation

Purpose

To have students plan and carry out an investigation

Student Outcomes

Students will learn to create an hypothesis and to develop a method for accepting or refuting their hypothesis using a small data set.

Overview

Using data from one GLOBE school, students investigate the heat buffering capacity of air, soil and water.

Time

Up to 1 week

Note: This activity may be repeated with other sets of data available on the GLOBE Web site.

Level

Middle: Grades 6 and up

Key Concepts

Explanations involve observations.
Evidence and logic are used to back claims.
Similar steps are used to conduct investigations.
Variables affect outcomes.
Expectations can affect outcomes.
Unexpected findings lead to new investigations.
Clear communication is important in science.

Skills

Organizing data
Recognizing and *describing* patterns
Interpreting graphs
Forming good research questions
Stating a testable hypothesis
Developing a research plan
Using math to analyze a problem
Communicating results

Processes

Scientific method
Student inquiry
Energy cycle

Materials and Tools

GLOBE Science Log
GLOBE Source Book
Calculator or spreadsheet software (not required)

Preparation

Students should be familiar with the steps to research outlined in the preceding Learning Activities: developing a question, stating a hypothesis, creating a methodology, mathematical analysis appropriate for their age level.

Prerequisites

None

Task
Using data from one school, determine if water or soil is a better buffer for heat change.

Preparation

If students are not familiar with the concept of specific heat, a classroom discussion of the relative heating capacities of air, water, and soil may be useful. Have students discuss from their own experiences how long it takes to heat air, relative to soil or water. Does water or soil cool more slowly? Students may need to review Middle Learning Activity 1: *Dancing With Data* for guidance in observations, research questions, and creating an hypothesis. The 'Using GLOBE Data for Student Research and Inquiry' introduction provides guidelines for creating a research project.

Students will need to access the Norfork Elementary (Arkansas, USA) graphs and data for one year from the GLOBE Data Source Book in printed form or from the CD. Data from many other schools may be found online at the GLOBE Web site.

What To Do and How To Do It

1. Examine the data of atmosphere, water, and soil temperatures. Make notes in your Science Log of any interesting patterns, trends or relationships you observe.
2. From your observations, write a well-stated research question about the relationship between air, soil, and water temperature.
3. State a testable hypothesis from your question. Make sure your terms are defined and that you can answer the question, "I will accept (or refute) my hypothesis if…"
4. Outline the method you will use to test the hypothesis:
   a. Which data will you use? Will you use averages?
   b. What variables do you have? Do you need to control any variable?
   c. How will you analyze the data?
   d. How will you present your findings?
5. Complete your research project following the steps you have outlined. Remember, it is acceptable to revise your project outline as you go if needed.
6. Analyze your results and reach a conclusion. Do you accept or refute your hypothesis?
7. Present your findings. What limitations did you have on your research? What further research might be done?

Advanced

LA1: I'll Try a Sample

Purpose

To introduce students to more advanced research methods

Student Outcomes

Students will be able to choose a sampling strategy for a research project and critically evaluate various sampling strategies.

Overview

Students will select a sample of GLOBE schools to analyze whether the global temperature range is changing.

Time

Up to one week

Level

Advanced

Key Concepts

There may be more than one answer to a question.
Some data may be obtained indirectly.
Expectations can affect outcomes.
Sampling bias can affect outcomes.
Explanations involve observations.
Evidence and logic are used to back claims.
Similar steps are used to conduct investigations
Variables affect outcomes.

Skills

Working with large data sets
Evaluating relationships between variables
Using the World Wide Web for research

Processes

Scientific method
Student inquiry
Energy cycle

Materials and Tools

GLOBE Science Log
Access to the GLOBE Web site
Calculator or spreadsheet software
World atlas (recommended)

Preparation

If students are not familiar with concepts covered in the Middle Inquiry Learning Activities, they should complete that section. Students should practice using the GLOBE visualizations area.

Prerequisites

Calculating range, percentages, averages

Making and reading a line graph

Outlining a research project

Using the GLOBE visualizations (tutorials are available on the GLOBE Web site)

Preparation

Sampling methods may be one of the most contentious elements of scientific research and whole books have been written on how to best choose representative samples when designing a research project. In this section students explore different ways to choose their samples and evaluate the results they obtain from different sampling methods. Before students begin the project a class discussion on why we sample, different sampling strategies, and bias in sampling may be useful. Students may be asked to bring in examples of research they find presented in newspapers or magazines that use different sampling methods and discuss how the results might have been different if the researcher had sampled in a different way.

This task can be done as a class project, with each group answering the same question using different sampling techniques. A 'role-playing' scenario may be created where different groups choose a sampling technique that they believe will best support their hypothesis.

Task – Strategies
Determine the difference in global temperature range between years.

What To Do and How To Do It

1. Decide on an hypothesis to test as to whether global temperature ranges are going up, down or remaining the same. If doing this as a class project, the entire class may choose one hypothesis to test.
2. Choose two or more years for which GLOBE atmosphere data are available.
3. Determine a method for calculating global temperature range.
4. Outline a method and a sampling strategy for choosing the data you will use. Some examples are:
   a. All GLOBE schools that meet the minimum data coverage that you determine
   b. All data from the Reference data found on the GLOBE Web site.
   c. A combination of data – GLOBE data, Reference data, other
   d. A random sample (subset) of data
   e. A stratified sample based on the same number or a weighted number of data points from different areas (i.e., continents, latitudinal zones, elevations, MUC codes, biomes, percentage of land in each latitudinal zone, etc.)
5. Perform your analysis using the method you outlined. Draw a conclusion based on this analysis. Were the global temperature ranges different? Which year had the greater range?
6. Repeat this activity using different sampling strategies or present the different strategies to other class teams. Compare your conclusions. Were the results the same?
7. Evaluate the strategies you used based on:
   a. Time involved to do the analysis
   b. Information gained using the various sampling strategies (is more information generated using some strategies?)
   c. Other advantages and disadvantages of each sampling strategy
      • Data quality (how were data collected?)
      • Data coverage
8. How can you make a determination on which is the *best* sampling method?

Advanced

LA2: Missing Data and Models

Purpose

To introduce students to creating and using a model

Student Outcomes

Students will be able to create a simple model and test and evaluate a model

Overview

Students will use data from one or more GLOBE schools to create a model to predict missing hydrology data.

Time

Up to one month

Level

Advanced

Key Concepts

There may be more than one answer to a question.

Some data may be obtained indirectly.

Models are predictive tools.

The accuracy of a model is based on a number of variables.

Skills

Working with large data sets

Evaluating relationships between variables

Using the World Wide Web for research

Processes

Scientific method

Student inquiry

Modeling

Materials and Tools

GLOBE Science Log

Access to the GLOBE Web site

Calculator or spreadsheet software

Optional: modeling or GIS software

Preparation

If students are not familiar with concepts covered in the Middle Inquiry Learning Activities, they should complete that section. Students may need to practice using the GLOBE visualizations area.

Prerequisites

Calculating range, percentages, averages

Making and reading a line graph

Outlining a research project

Using the GLOBE visualizations (tutorials are available on the GLOBE Web site)

Preparation

A model is a tool used to predict what may happen in the future, to explore a system on a small scale or to fill in missing gaps in data collection. Have students brainstorm their own definition of a model. What types of models are used by different professions? Why might an architect build a model of a building? How would a weatherperson use a model? Why would we model the effects of global cooling or warming? What other professions use models? – criminologists, historians, movies, medicine, etc.

Models may come in various forms. A physical model might be a miniature of a building or a map. How are physical models different from the real thing? Models may also be mathematical with the variables represented by letters or numbers. The formula for a line is a mathematical model of that line. Models can also be descriptive. Good use of words may create a model in your mind of a person or place.

The model for this activity will be one that can be used for prediction or to fill in missing gaps in a data set.

Task – Create a model
Develop a model to predict water or soil temperature.

What To Do and How To Do It

A GLOBE school has been collecting atmosphere data for two years. They have only been collecting water temperature data* for one year. They want to do a two year study, however, requiring water temperature data. Can they use their atmosphere data to create a model to accurately predict their water temperature data?

*or soil data

1. Identify a GLOBE school for your project that has at least two years of air temperature data and at least one year of water and/or soil temperature data.
2. Determine the variables that you believe will most affect water temperature or the relationship between air and water temperature at this site (i.e., maximum, minimum, or current air temperature, mean temperature, precipitation, season, land cover, etc.)
3. Decide which variable you believe is most closely related to water temperature. For instance, you might decide soil temperature or mean air temperature is most closely related to water temperature.
4. Decide which variable(s) most affect this relationship. Does this relationship vary with season, precipitation, etc?
5. Write a model for predicting the water temperature. Two ways you might state your model are
   a. If I find that ___________, then the water temperature will be ___________. For example, "If it is not raining, the water temperature will be 3 degrees below the mean air temperature. If it is raining ….. "
   b. As a mathematical formula: Water temperature (W) = Mean Temperature (M) $\pm$ 3. (plus if Precipitation (P) > 0.5)
6. Test the model with actual data. NOTE: Since you cannot use the same data to create the model and test the model, make sure in your research design to have data reserved for testing. For example, you might use data from 1996 to create your model and test its accuracy by predicting data from 1997.
7. Determine the accuracy of your model. How often were you able to predict the water temperatures accurately? What range of error did you find?
8. Refine the model, if necessary. Can you change anything to make the model more accurate?
9. Try using your model with other sites. Does the model work for other sites? Can you identify variables that make the model less effective for other sites?

Further Investigations

Can the model predicting water or soil temperature be improved with additional variables. For instance, can water temperature be predicted more accurately using soil temperature or both soil and air temperatures?

Advanced

LA3: More and More Data

Purpose

To introduce students to more advanced research methods and additional data sets.

Student Outcomes

Students will be able to use modeled data in a research project.

Overview

Students will use the modeled data available on the visualizations of the GLOBE Web site to do a research project.

Time

Up to 3 months

Level

Advanced

Key Concepts

There may be more than one answer to a question.

Some data may be obtained indirectly.

Models are predictive tools.

The accuracy of a model is based on a number of variables.

Explanations involve observations.

Evidence and logic are used to back claims.

Similar steps are used to conduct investigations

Skills

Working with large data sets

Evaluating relationships between variables

Using the World Wide Web for research

Critically evaluating modeled data

Developing a research project

Processes

Scientific method

Student inquiry

Materials and Tools

GLOBE Science Log

Access to the GLOBE Web site

Calculator or spreadsheet software

Optional: modeling or GIS software

World atlas (recommended)

Preparation

If students are not familiar with concepts covered in the Middle Inquiry Learning Activities, they should complete that section. Students may need to practice using the GLOBE visualizations area.

Prerequisites

Outlining a research project

Using the GLOBE visualizations (tutorials are available on the GLOBE Web site)

Interpreting isopleth maps

Preparation

Students should be familiar with the steps to doing a research project. If they are not, review some of their work on the previous learning activities or have them do additional projects using the formats from earlier activities. It is always recommended that students turn in a project proposal for review before they begin the actual work on a research project.

The GLOBE Web site provides numerous data sets beyond the GLOBE student data that may be visualized on the GLOBE Web site in the same manner as the GLOBE student data maps. Some of these include modeled weather data, soil moisture, evaporation, and albedo. If students are not familiar with using the GLOBE mapping tools, a tutorial is available on the GLOBE Web site to help them get started.

The GLOBE Earth Systems poster is also a useful tool for introducing students to modeled data sets.

Task – Use Modeled Data
Use modeled data in a research project

What to Do and How to Do It

1. Examine the modeled data available on the GLOBE Web site or from other web sites or resources you may find.
2. Compare different types of modeled data.
3. Compare GLOBE student data to the modeled data sets.
4. Develop and do a research project based on your observations of GLOBE student data and modeled data.
5. Analyze your research in terms of not only your own analysis, but in terms of the use of modeled data.
6. Create a presentation of your research suitable for posting in the Student Investigations area on the GLOBE Web site.